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The use of termites and other soil fauna to develop soils on strip mine spoils[1]

George Ettershank, Ned Z. Elkins, Perseu F. Santos, Walter G. Whitford, and Earl F. Aldon[2]

A laboratory study showed that soil arthropods, especially naturally occurring subterranean termites, can produce beneficial changes in the physical and chemical characteristics of mine spoil material.

Keywords: Soil arthropods, soil fauna, reclamation mine spoils.

Reclamation of spoils from the strip mining of coal in the arid Southwest currently consumes much water and energy. Current research is seeking ways of reducing these costs. Most current reclamation techniques are based on the establishment of native plant species. In areas of low rainfall, supplemental watering and/or fertilization is used to maintain these species.

Undisturbed or natural soils contain bacteria, fungi, and an assemblage of arthropods which make up the soil community. The soil community is a complex organization of interdependent species which process dead plant material and convert it into mineral soil, fix nitrogen, redistribute soil particles, enhance aeration, and generally affect the structure of a soil (Witkamp 1971). Mine spoils usually lack this biological soil community.

This implies that future management practices in mine spoil reclamation must be aimed at establishing a soil biota, as well as a supportive organic substrate for the soil organisms. The effect of the biota, working on organic material incorporated with the spoil, should be to create a soil environment conducive to vigorous and sustained plant growth.

Little is known about the structure of arid soil communities, and still less is known of the role soil arthropods play in maintaining that structure. To begin to understand this function, three studies were conducted to determine the structure of the soil arthropod community on unmined areas, compare those with mined areas, and measure arthropod populations of areas subjected to several reclamation practices on the Pittsburg and Midway Corp. McKinley Mine near Gallup, N. Mex.

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[2]Ettershank is Research Professor, Elkins and Santos are Graduate Students, and Whitford is Professor of Biology, New Mexico State University, Las Cruces. Aldon is Principal Hydrologist, Rocky Mountain Forest and Range Experiment Station, located at Station's Research Work Unit at Albuquerque, in cooperation with University of New Mexico; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.

Methods

Study 1

The density of colonies of the termite *Reticulitermes tibialis* Banks. naturally found on unmined areas near McKinley Mine was estimated on three standard bait unit-grids (toilet paper rolls — 100 rolls/grid in 10 rows of 10 baits at 1-m intervals). The areas sampled were in pinyon-juniper and sagebrush communities at an elevation of 2,130 m. These bait unit-grids were checked approximately monthly for termite activity, during visits to the site in the summers of 1977 and 1978.

Study 2

In September 1977, three bait rolls containing several hundred termites (*Reticulitermes tibialis* Banks.) were placed on top of three 2-liter cans of unamended mine spoil. The spoil material was moistened, and the container and roll were covered with aluminum foil to retain moisture. The containers were incubated at room temperature, 20° to 25° C, during the experiment. Two of the three containers had flourishing colonies of live termites when the experiment was terminated 9 months later, in June 1978. Spoil material without termites was held in a container in the same laboratory. Chemical and physical soil analyses were conducted using standard laboratory methods (Sandoval and Power 1978).

Study 3

Spoil samples were collected from three different types of reclamation areas at the McKinley Mine and on three unmined areas. Soil was sampled on unmined areas in open grassland, under fourwing saltbush (*Atriplex canescens* (Pursh.) Nutt.) and under one-seed Juniper (*Juniperus monosperma* (Engelm.) Sarg.). Reclaimed sample areas were: spoil amended with bark, spoil amended with straw 1 and 2 years previously, and spoil "topsoiled" 1 and 2 years previously with soil taken from a nearby borrow area. Samples were transported to the laboratory in an insulated container. Samples were thoroughly mixed, and 500-700 cm^3 were placed in a modified Tullgren extractor. Microarthropods were collected in water, counted and identified.

Results and Discussion

Study 1

An average of 1,850 termites (*R. tibialis*) was collected on each of the 100-m^2 grids, which converts to an estimate of 185,000 termites per hectare (92,500 foragers per acre). In other studies, it has been observed that bait rolls greatly underestimate subterranean termite populations, because only a fraction of the physiologically active termites feed at the surface at any one time. These data, however, indicate that *R. tibialis* is an important component of pinyon-juniper and sagebrush communities in northwestern New Mexico.

Study 2

This preliminary study with *R. tibialis* on strip mine spoil with only paper bait rolls as an energy source is indicative of the ability of these organisms to cause rapid changes in chemical and physical properties of spoil material. For termites to utilize the energy of a relatively pure form of cellulose (paper, for example), they need a variety of inorganic salts for their own metabolism and to maintain the activity of their symbiotic microflora (Breznak et al., 1973). To obtain these salts in nature, termites ingest quantities of soil, pass it through their digestive system, and use this material mixed with indigestible food and wastes (fecal material) to form a paste, termed "carton", which sets on drying. This carton is used extensively to line their galleries (Lee and Wood 1971). This activity had a marked effect on the chemical as well as the physical properties of the spoil used in this study (table 1). Some ions were released from the insoluble state and others bound into soluble salts after passage through the termite gut, e.g. soluble Na^+ and $SO_4^=$ were reduced while HCO_3^- and $PO_4^=$ increased. Unfortunately, total nitrogen and total carbon could not be obtained on these samples. In a separate study in southern New Mexico, we found that soil from a profile containing termite gallery carton contained 2,460 ppm total N in comparison to 480 ppm total N in non-carton soil.[3]

There were marked differences in texture and appearance of the untreated spoil when

[3] *Ettershank and Whitford, unpublished data.*

Table 1.—Estimated chemical and physical means of mine spoil from the McKinley Mine, treated with termites and paper bait rolls as an energy source

	EC mmhos	Saturated paste pH	Na^+	Ca++	Mg++	K^+
			meq/l			
Spoil	3.37	7.48	47.7	0.97	0.52	0.59
Spoil/termites	1.66	7.63	16.6	3.00	0.72	0.47
	$SO_4^=$	CO_3	HCO_3^-	Cl^-	$PO_4^=$	NO_3^-
	meq/l				ppm	
Spoil	46.5	0	0.2	0.06	0.02	3.9
Spoil/termites	17.2	0	2.6	0.59	0.26	0.55
	% Organic matter	% Saturated		% Sand	% Silt	% Clay
Spoil	3.96	71.1		35.2	26.0	38.8
Spoil/termites	2.13	23.2		52.2	20.5	27.3

compared to termite worked spoil (fig. 1). The termite amended spoil (lower part fig. 1) was more friable and uniform and was observed to wet evenly. The unworked spoil (upper part fig. 1) was lumpy and wet unevenly; indeed, this material had to stand in water to become saturated. The termite activity, resulting in the formation of carton, also had beneficial effects on the physical characteristics of the spoil by breaking up the large chunks and mechanically mixing the material, producing a sandy-clay-loam texture (table 1, fig. 1). It will be seen from the mechanical analysis in table 1 that in the spoil with termites, the percent of sand increases at the expense of silt and clay. This apparent anomaly is a result of the termites selectively removing silt and clay to build galleries in the paper bait roll. In the field, this activity would enhance porosity, percolation, and aeration of the substrate.

Study 3

Straw amended spoil had a complex microarthropod fauna on both the 1- and 2-year-old areas (table 2).

There were no differences in density of the soil microarthropod fauna under juniper and in pine bark amended spoil (table 2). The presence of soil microarthropods is indicative of a mature or maturing soil ecosystem. Santos et al. (1978) found that Mesostigmatid mites (which were found on both undisturbed and reclaimed areas) are typical of arid soils. In detailed studies of litter bags on the Jornada site, near Las Cruces, N. Mex., the authors consistently found that high population densities of mites are associated with high activity of soil micro-organisms (fungi and bacteria). Some of the soil Prostigmatid mites are fungivores and/or nematode predators, and greatly affect rates of organic matter breakdown and mineralization.

Samples from spoil covered with a 0- to 5-cm layer of borrow soil but with no mulch had no microarthropod fauna (table 2). The absence of soil microarthropods on spoils top-dressed with borrow soil suggests that this "topsoiling" without the addition of organic mulch will not restore the soil microarthropods quickly. Additional studies are underway which will include gathering data on fungi and bacteria. Raw mine spoil is amended with organic matter and inoculated with soil microarthropods to determine if the population will rapidly build up and yield a soil that will sustain a community of desirable plant species.

Future Work

Although these are preliminary studies, they suggest some procedures for re-establishing soils on strip mine spoils more rapidly and possibly at a lower cost than at present. It is evident that soil arthropods, especially subterranean termites in an arid region, can produce marked and beneficial changes in the physical and chemical characteristics of mine spoil material when the termites are provided with a suitable source of energy (paper, wood, straw, etc.). Techniques for establishing termite colonies on coal strip mine spoils are under study.

Table 2.—Average numbers and taxa of microarthropods extracted from 500-700 cm^3 of soil from disturbed and undisturbed areas at the Pittsburg and Midway McKinley Mine

Taxon	Open	Under *Atriplex canescens*	Under *Juniperus monosperma*	Spoil with bark	Spoil with straw 1 year	Spoil with straw 2 years	Spoil with borrow soil 1 year	Spoil with borrow soil 2 years
Cryptostigmata Oribatei	11	23	22					
Prostigmata Nanorchestidae	0	0	0	44	5	7	0	0
Other Prostigmata	18	36	76	2	7	8	0	0
Mesostigmata	0	0	0	0	0	17	0	0
Astigmata Acaridae	0	0	0	0	30	20	0	0
Other Mites	21	51	76	113	12	18	0	0
Collembola	2	0	0	20	0	6	0	0
Insects	2	4	10	6	4	0	1	0
Total	54	114	184	185	58	76	1	0

A

B

Figure 1.—Mine spoil material from McKinley Mine which had been subjected to termite activity: (A) mine spoil not worked by termites compared with (B) mine spoil that had termites feeding on paper bait rolls. Note the friable, granualr appearance of the spoil containing termite carton in contrast to the untreated spoil. (15 X magnification)

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